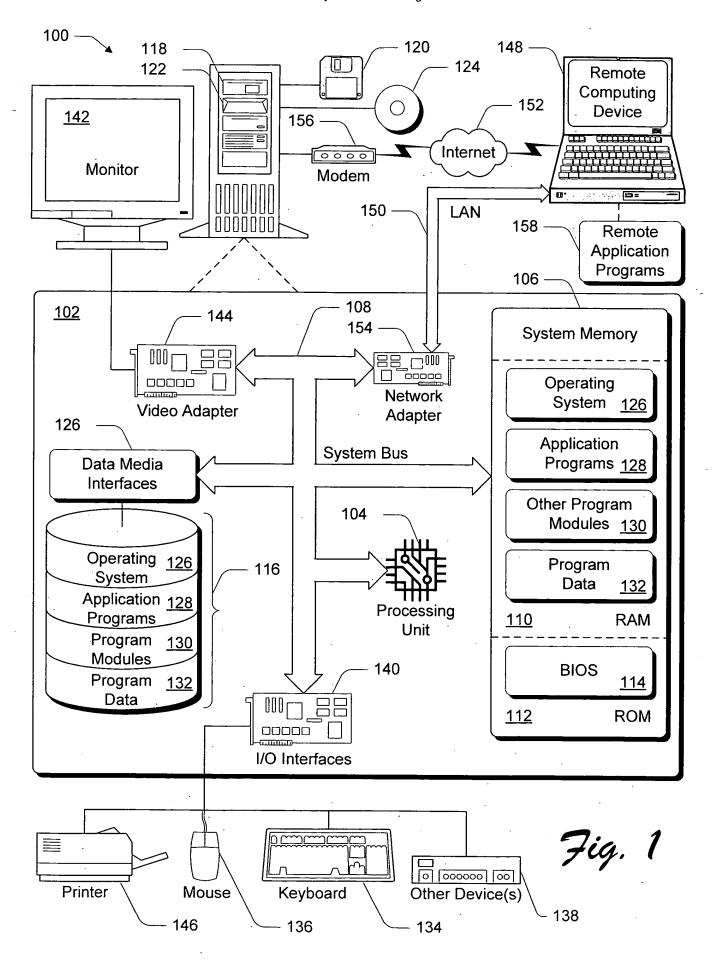
Docket No.: MS1-1904US

<u>Inventors</u>: Lie Lu, Hong-Jiang Zhang <u>Title</u>: Beat Analysis of Musical Signals



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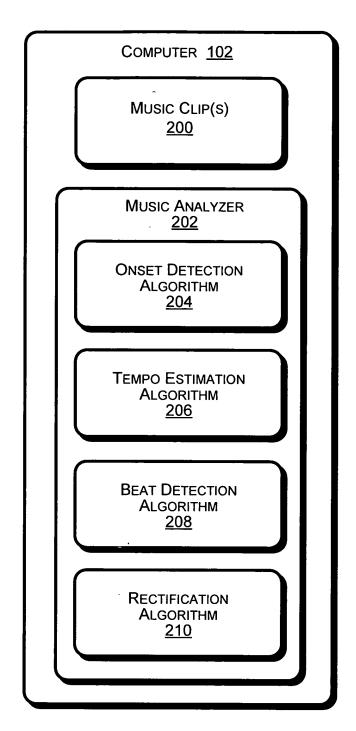
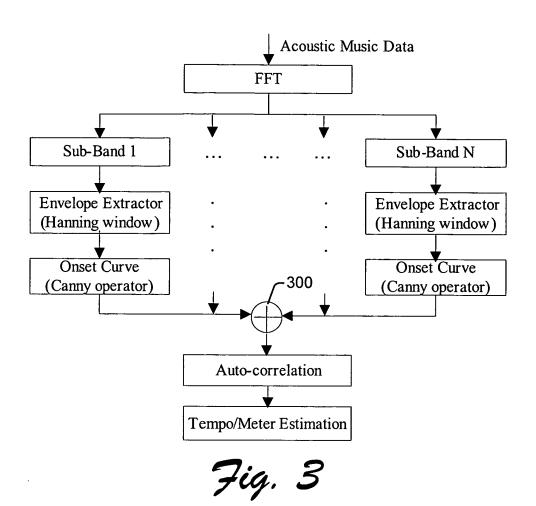
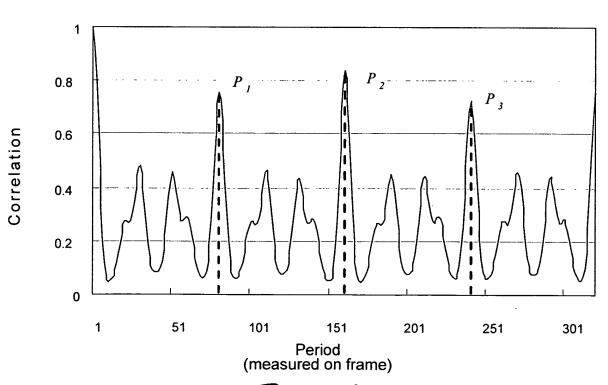
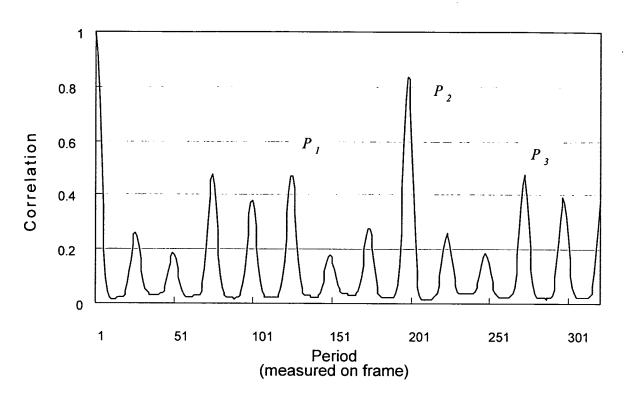


Fig. 2







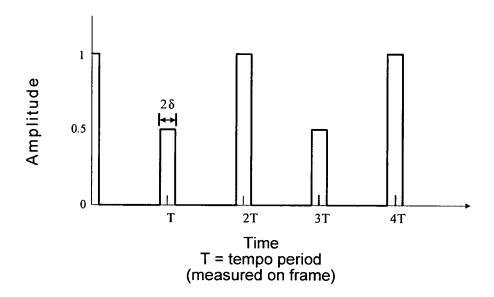
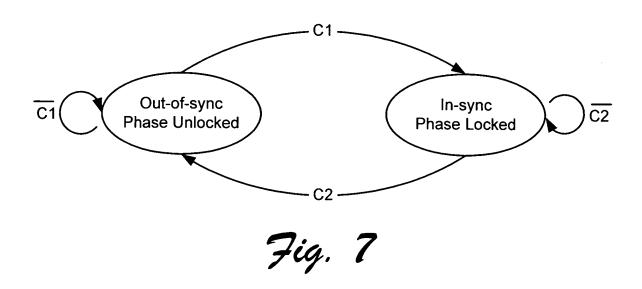


Fig. 6



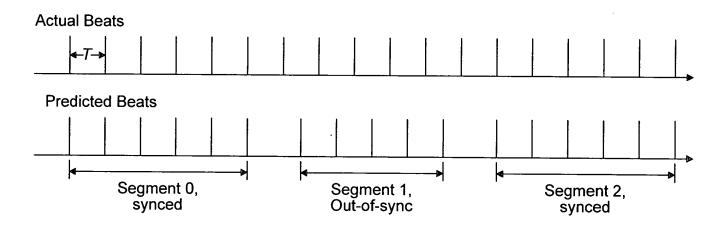


Fig. 8

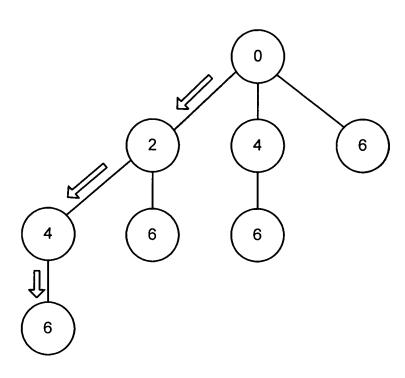


Fig. 9

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- 1002

Determine onsets from a music clip:

- down-sample music clip to a uniform format
 - e.g., 16 kilohertz, 16 bit, mono-channel sample
- divide music clip into plurality of frames
 - e.g., 16 microsecond frames
- calculate the frequency spectrum of each frame e.g., using FFT
- divide each frame into octave-based frequency sub-bands e.g., 6 octave-based sub-bands
- calculate amplitude envelope of a lowest and highest sub-band
 - convolve lowest and highest sub-band with a half raise cosine Hanning window
- detect onset curve from the amplitude envelope
 - calculate variance of amplitude envelope of lowest and highest sub-band
- determine onsets as local maximum variances in amplitude envelope

- 1004

Estimate tempo from onset curve of music clip:

- sum onset curves of lowest and highest sub-band to determine onset curve of music clip
- generate auto-correlation curve from onset curve
- calculate maximum common divisor of prominent local peaks of autocorrelation curve

- 1006

Estimating a length of a bar of the music clip:

- calculating the length as a maximum common divisor of three peaks in auto-correlation curve if the three peaks are evenly spaced within the tempo of the music clip
- if the three peaks are not evenly spaced within the tempo of the music clip, selecting the position of the maximum peak within the tempo as the length

To Block 1008, Fig. 11

Fig. 10

FROM BLOCK 1006, Fig. 10

- 1008

Determine beat candidates from onsets:

- calculate a beat confidence for each onset
 - represent rhythm pattern of music clip with beat pattern template
 - match beat pattern template along onset curve of music clip
- detect beat candidates from onsets based on onset beat confidence
 - adaptively set a threshold
 - compare beat confidence for each onset to threshold

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<u>Detect segments of beat sequence to determine parts of sequence synced to actual beat and parts of sequence not synced to actual beat:</u>

- find at least 3 continuous beat candidates having intervals of one or more tempos
- confirm the at least 3 continuous beat candidates as actual beats synced to the actual beat phase

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Rectify segments of beat sequence that are out-of-sync with actual beat phase:

- build phase tree from the segments
 - determine if a subsequent segment shares the same beat phase as a current segment
 - if the subsequent segment shares the same beat phase as the current segment, insert subsequent segment into phase tree as a child segment of the current segment
 - iterate previous 2 steps until all segments are processed
- search phase tree to determine a largest sequence of segments that share a same beat phase
- assuming that largest sequence of segments are synced segments that follow the actual beat phase
- assume that all segments that are not synced segments are out-of-sync segments
- rectify the out-of-sync segments
 - follow the actual beat phase for the out-of-sync segments

Fig. 11